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International Competition Between Satellite and Fiber Optic Carriers: A Geographic Perspective*

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International telecommunications traffic relies entirely on two modes of transmission, satellites and fiber optics, which exhibit considerable but not complete fungibility. This article explores the economic and geographic dimensions of these two industries in the context of the growing market in global data and telephony traffic. First, it summarizes the changing conditions that have accentuated competition between them, including deregulation, technological change, and globalization. Next, it examines the changing cost structures, transmission capacities, and traffic volumes for each technology in the critical transatlantic and transpacific markets. Throughout, it documents the steady encroachment by fiber optics firms that threatens the viability of commercial satellite operators, a challenge the latter hope to meet though the growth of the cellular telephone market. **Key Words: fiber optics, satellites, telecommunications.**

The centrality of global telecommunications to the world economy has been demonstrated in a large and growing literature by geographers (Warf 1995; Graham and Marvin 1996; Wheeler, Aoyama, and Warf 2000; Wilson and Corey 2000), a body of work that has gone far to erase what Hillis (1998) noted is the "invisibility" of communications within the discipline. The ability to transmit vast quantities of information in real time over the planet is crucial to what Schiller (1999) called digital capitalism, the flexible, globalized, post-Fordist system of market relations that dominates the world economy. No large corporation could operate in multiple national markets simultaneously, coordinating the activities of thousands of employees within highly specialized corporate divisions of labor, without access to sophisticated channels of communications. Indeed, the exploding demand for high bandwidth communications has been a major force behind the growth of the international communications infrastructure, as Sassen's (2000) well-known model of global cities argues. Therefore, an understanding of telecommunications is important to understanding broader issues pertaining to globalization and the world economy, including the complex relations between firms and nation-states. Within geography, the literature has focused on the urban impacts of telecommunications (Graham and Marvin 1996) and geographies of the Internet (Malecki 2001; Kellerman 2002; Crampton 2003).

The telecommunications industry itself is not monolithic, but is composed of several rival segments, often centering on different technologies with varying capacities, strengths, and weaknesses. Historically, state-owned or regulated telephone companies during the POTS (plain old telephone service) era (Graham and Marvin 1996) relied on copper cables to transmit analogue data, a technology largely surpassed among high-end users following the microelectronics revolution and the subsequent digitization of information.

Today, two technologies—satellites and fiber optics lines—exclusively dominate the technologies deployed by the global telecommunications industry. The transmission capacities of both of these modalities grew rapidly in the 1980s and 1990s, a reflection of several intertwined trends in the global economy: deregulation, enormous technological change, and the shifting nature of demand. Firms engaged in

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international traffic (e.g., multinational corporations, financial institutions, telephone and television companies) frequently employ both technologies, often simultaneously, either in the form of leased circuits from shared corporate networks constructed by consortia or leased time from satellite companies. To meet this demand, roughly 1,000 fiber optics firms and two dozen public and private satellite firms compete to provide international telecommunications service, the vast majority of which originate in economically developed countries. Graham (1999) noted that the skein of fiber lines linking the world constitutes the core of interlinked urban systems, or what Castells (1996) more prosaically referred to as the "space of flows." Satellites have received much less attention from geographers. Monmonier (2002) noted their role in surveillance and spying, but to date satellites remain a black hole in the geographical literature on communications.

Although they overlap to a great extent, satellite and fiber optics carriers exhibit an important degree of market segmentation. Economically, both reflect the typical cost structure of telecommunications—that is, high fixed costs and barriers to entry and low marginal costs. However, these carriers serve overlapping, but slightly different markets: satellites overwhelmingly dominate mass media transmission, although fiber carriers have recently begun to invade this market (e.g., cable television). Fiber carriers are heavily favored by large corporations for data transmissions and by financial institutions for electronic funds transfer systems, in part because of the higher degrees of security and redundancy this medium offers (Langdale 1989; Nijkamp and Vleugel 1993; Warf 1995). Telecommunications markets that can be equally well served by both technologies, such as telephony and Internet traffic, are the focus of particularly intense competition. Television, long transmitted via satellite, has increasingly migrated to fiber (i.e., cable TV) and now comprises 25 percent of the traffic in that sector (www.global-electronics.net).

These two types of carriers are differentiated geographically as well. Because their transmission costs are unrelated to distance, satellites are optimal for low-density areas such as rural regions and remote islands, where the relatively high marginal costs of fiber lines are not competitive. In contrast, fiber optics carriers prefer large metropolitan regions where dense concentrations of clients allow them to realize significant economies of scale and where frequency transmission congestion often plagues satellite transmissions. The Atlanta metropolitan region, for example, exhibits 400,000 miles of fiber optic lines, which have been important to the revival of the revival of downtown regions and have enhanced its competitive position within the national urban hierarchy (Walcott and Wheeler 2001). Satellites are ideal for point-to-area distriution networks, whereas fiber optic lines are preferable for point-to-point communications, especially when security is of great concern. In short, satellite and fiber optics services are quasi-substitutable, serving overlapping but not identical sectoral and geographic markets.

Historically, the primacy of each technology has varied over time, and continues to do so. From approximately 1959 to 1980 (i.e., during the POTS era and before the invention of fiber optics), satellites enjoyed limited competition from transoceanic copper cable lines with low capacity rates. From the 1970s to the 1990s, the microelectronics revolution allowed terrestrial fiber optics lines to erode the market share of traffic held by satellites (Landler 1995; Maclean 1995). More recently, the rapid growth of wireless and cellular phone traffic has led to a resurgence of low-orbiting satellites, giving new hope to an increasingly desperate industry. Clearly there is no inevitability in the hegemony of either industry: their competition has dramatically expanded capacity, lowered transmission costs, and generated cost savings that are particularly important for large corporate clients.

Causes of Enhanced Competition

The marked acceleration in competition between satellite and fiber optics carriers can be traced to three major causes, deregulation, globalization, and technological change, all of which reflect the broader emergence of post-Fordist capitalism in the late twentieth century. In contrast to the relatively stable system of telecommunications providers under Fordism, in which telephone services predominated, technological evolution was minimal, and state-regulated monopolies were the norm, the current epoch is one of rapid change in every facet, including explosive increases in supply, demand, transmission capacity, declining prices, the entrance of numerous private carriers, and accelerated technological change.

Deregulation

The lifting of government controls is a fundamental part of the policy initiatives of the post-Keynesian state (Leyshon 1992; Tickell and Peck 1995). The deregulation of telecommunications around the world centered on the transformation from state-owned or regulated monopolies to competitive, private carriers. This process was initiated by the United States with the breakup in 1984 of AT&T, which had long enjoyed a monopoly over domestic telephony and was broken up by an antitrust suit. The 1996 Telecommunications Act further eliminated regulatory oversight, effectively ending the boundaries between local and long-distance traffic and opening the door to a wave of mergers and acquisitions (Warf 2003). Soon thereafter, British Telecommunications, France Telecom, and Deutsche Telekom were partially or totally sold en masse to private investors, and in Japan the monopoly long held by Nippon Telegraph and Telephone (NTT) was broken by government fiat (although, like France Telecom, it remains largely publicly owned). The World Trade Organization's Basic Telecommunications Agreement, which went into effect in 1998, also fostered competition around the world (Drake and Noam 1998). Today, state-owned or regulated telecommunications monopolies are increasingly rare around the world. The consequences of deregulation were dramatic for the market structure of telecommunications, including new competitors, improved service, and rapidly falling costs, although Graham and Marvin (1996) noted that in this climate, providers may freely engage in "cherry picking"—servicing only high-profit clients at the expense of the needy and disempowered.

The deregulation of the U.S. satellite industry began with the 1972 Federal Communications Commission's "open skies" policy, which started an era of privately owned commercial satellites (Kinsley 1976). At the end of the Cold War, American government restrictions on the sale of satellite data and images were gradually lifted. In 1997, limitations were eliminated on international satellite service providers operating in the United States, previously restricted in the amount and type of services they could provide (Price 1998). Globally, this process took the form of the erosion in the quasi-monopoly position held by the largest and most comprehensive organization involved in the regulation of global satellite traffic, the International Telecommunications Satellite Organization (Intelsat), a private, nonprofit organization headquartered in Washington, D.C., with representatives from 134 governments around the world (Kildow 1973; Akwule 1992). Intelsat owns and operates a fleet of 22 high-powered spacecraft in geosynchronous orbit over the Atlantic, Pacific, and Indian oceans (Figure 1), far more than any other global or regional satellite system. Intelsat's large number (387) of international earth stations (which are the only kind capable of handling international traffic) is more than 80 percent of the world's total and has long endowed it with near-monopoly status in this industry. The network boasts of being the only truly global satellite system. It is by far the world's leading provider of satellite services, including the transmission of one-half of all international phone calls (although this share has been rapidly declining). Indeed, distinct if imperfect parallels can be drawn between AT&T's status domestically and Intelsat's hegemony internationally. Some critics allege that the lack of competition in the satellite industry is to blame for its recent woes in light of the rise of fiber optics.

The worldwide wave of deregulation in the 1980s and 1990s was closely associated with the gradual decline of Intelsat's monopoly status (Harwood, Lake, and Sohn 1997; Pfeifenberger and Houthakker 1998). In the post–Cold War era, Intelsat has been faced with three major sources of competition. The first stemmed from national satellite systems erected by several individual nations, including India, Brazil, Mexico, China, France, and Thailand (Table 1). The second source came from a new generation of private satellite firms, including: COMSAT, starting in 1979; PANAMSAT (the Pan-American Satellite Corporation), founded in 1988 to "bust open" the Intelsat monopoly in Latin America; ORIONSAT, started in 1989; Motorola's venture, Iridium, starting in 1990, though this firm subsequently went bankrupt; Odyssey, a joint venture of TRW and Teleglobe; and Loral's Orion project, all of which sprouted up largely to take advantage of the explosive

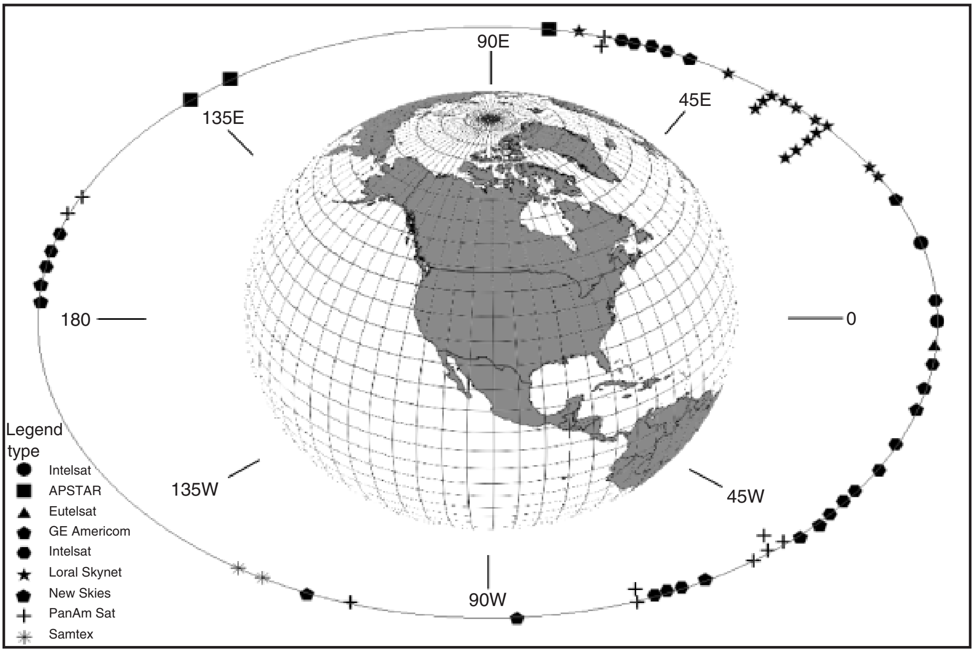

Figure 1 *Orbital positions of major geostationary satellites. Source: Redrawn from Staple (2004).*

Table 1 *World's twenty largest satellite carriers, 2001*

	Headquarters nation	Annual revenues ($ millions)
Intelsat	United States	1,100.0
PanAmSat	United States	870.0
SES Astra	Luxembourg	655.5
Eutelsat	France	593.5
SES Americom	United States	506.7
Loral Skynet	United States	388.9
JSAT	Japan	298.2
New Skies Satellites	Netherlands	209.0
Telesat Canada	Canada	201.6
Space Communications Corp.	Japan	170.8
Arabsat	Saudi Arabia	155.0
Star One	Brazil	130.5
Satmex	Mexico	128.0
AsiaSat	Hong Kong	124.3
Telenor	Norway	121.6
Shin Satellite	Thailand	116.8
Hispasat	Spain	94.9
SingTel/Optus	Australia	85.9
Korea Telecom	South Korea	76.3
Russian Satellite Communications	Russia	61.0

Source: Silverstein (2001).

cellular phone market. The third source of competition for Intelsat is fiber optics. Concerns over the implications of fiber optics arose as early as the 1980s (e.g., Layton 1986), when the first transoceanic lines were laid. The migration of many clients from satellites to fiber optic lines significantly reduced Intelsat's share of international switched telephony services (Landler 1995) and, somewhat later, video transmission as well.

Globalization

Competition between satellites and fiber optics reflects the rapid expansion of demand for international telecommunications, itself driven by the steady growth of multinational corporations, global business travelers, international tourism, mounting transcontinental telephony, and cross-border sales of television shows, all of which have greatly expanded the markets for carriers and ushered in new opportunities. International sales of services, for example, now comprise 25 percent of world trade (Dicken 2004), a phenomenon made possible by, and in turn enhancing, global telecommunications. As a result, transborder telecommunications traffic has increased by more than 15 percent per year over the past two decades.

Deregulation and globalization opened the door for a proliferation of new fiber optics carriers. Until the 1990s, all commercial fiber lines were built, used, and paid for by consortia of monopoly carriers such as AT&T, British Telecomm, Japan's Kokusai Denshin Denwa (KDD)—a group known informally in the industry as "The Club." AT&T, for example, ventured aggressively into the international fiber optics market as it globalized in the face of declining market share in the United States, often by entering strategic alliances (Warf 1998). AT&T's Submarine Systems operates a fleet of six cable ships to service its 230,000 kilometers of undersea cable. Because large fiber networks are generally owned and operated by consortia, no separate listing of individual carriers is feasible; Table 2 lists the major submarine cable networks in place in 2003 for the two largest markets across the Atlantic and Pacific Oceans. Under the Club system, capacity was allocated and payments were made before or during construction of the network. Members were required by national regulators to sell capacity to nonmembers on a nondiscriminatory basis close to cost. However, as deregulation encouraged new entrants into the cable markets, the Club system began to fragment. New firms now often lease excess backhaul capacity from former monopolies in order to connect domestic networks to the international system.

The geography of global fiber networks centers primarily on two distinct telecommunications markets crossing the Atlantic and Pacific Oceans, connecting three of the major engines of the world economy, North America, Europe, and East Asia. Because large corporate users are the primary clients of such networks, it is no accident that the original and densest web of fiber lines connects London and New York (Figure 2), a phenomenon that extends historically to the telegraph and telephone (Hugill 1999). In 1988, in conjunction with MCI, British Telecommunications, and KDD, AT&T initiated the world's first transoceanic fiber optic cable (TAT-8). Starting with Trans-Pacific Cable (TPC-3) in 1989, a growing web of transpacific lines mirrored the rise of East Asian trade with North America (Figure 3), including the surging economies of the newly industrialized countries.

Despite exaggerated claims that telecommunications render distance meaningless (Cairncross 1997), the geography of fiber optic lines reflects the accumulated imprints of successive rounds of investments in space and time. The placement of terrestrial networks reflects and constructs a palimpsest of differing technologies and changing markets sedimented over time and space, a notion well captured by Massey's (1984) classic work on spatial divisions of labor. Because the implementation of fiber lines reflects the powerful vested interests of international capital, these systems may be seen as "power-geometries" (Massey 1993) that ground the space of flows within concrete material and spatial contexts.

In addition to the two major markets, fiber lines have extended into several smaller ones. In 1997, AT&T and several other firms opened the self-healing Fiberoptic Link Around the Globe (FLAG), a 27,300-km cable connecting Asia and Europe, the world's longest submarine telecommunications network and the first to carry transmissions by nontelecommunications firms (Denniston 1998). Club members have also constructed regional systems, such as the 12,000-km Asia Pacific Cable Network, the Caribbean Fiber System, and several networks in Europe. Even Africa, long marginalized in global telecommunications, saw AT&T's Africa ONE system circumnavigate that continent in 1999 with a 39,000-km-long, high-capacity digital undersea fiber optic network.

Table 2 *Major international fiber optics cable providers, 2003*

Transatlantic	**Transpacific**
360altantic	China–U.S. Cable System
Apollo	Japan–U.S. Cable System
Atlantic Crossing	Pacific Crossing
Columbus-III	Southern Cross Cable Network
FLAG Atlantic	TyCom Transpacific
Gemini Cable	East Asia Crossing
TyCom Transatlantic	Dishnet DSL
Yellow/Atlantic Crossing	

Source: www.igigroup.com.

Technological Changes

Telecommunications is perhaps the industry most profoundly affected by the microelectronics revolution, including the switch from analogue to digital information and the merger of

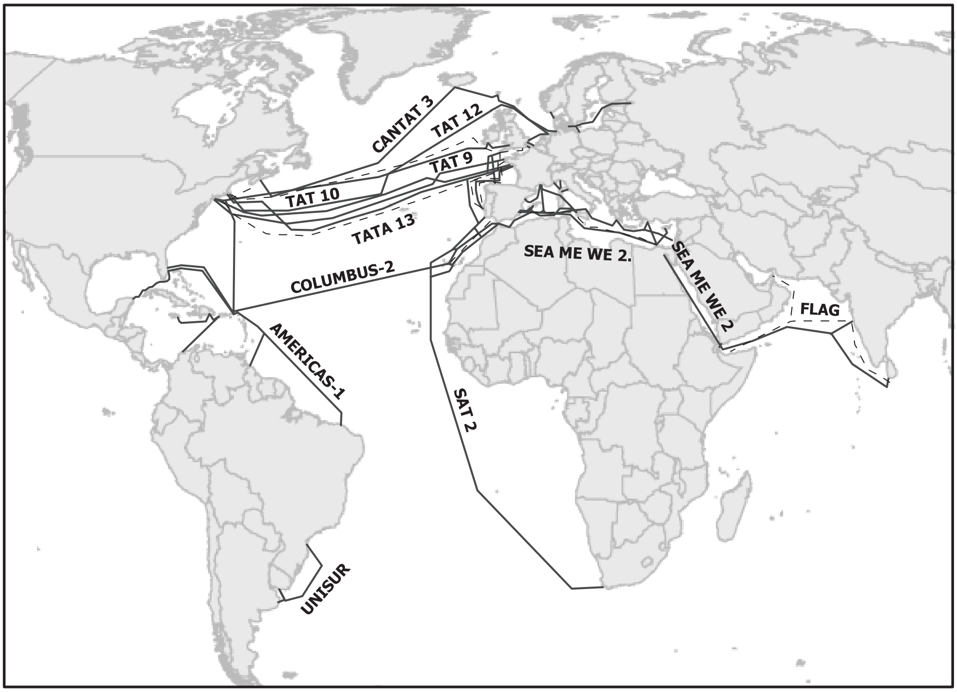

Figure 2 *Transatlantic fiber lines.*
Source: Redrawn from Staple (2004).

computing and communications. The introduction of Integrated Services Digital Networks (ISDN) greatly facilitated this process, as did the emergence of TCP-IP protocols and packet switching for the Internet. New repeaters introduced in the early 1990s, which pick up, amplify, and transmit signals every 50 miles, further reduced costs and improved transmission quality. Optical fiber transmissions were greatly enhanced by the development of optical amplifiers that simplified the electronic repeater, by increased reliability, and by dense wavelength division multiplexing (DWDM), which made it possible to transmit multiple wavelengths over a single pair of fibers, thereby raising maximum transmission capacities from 280 megabits per second in the 1980s to 12 terabits by 2003, a 42,800 percent increase. Moreover, the number of strands per fiber cable has increased from two to eight pairs. The FLAG Atlantic-1 (FA-1) cable, which entered commercial service in June 2001, has by itself almost doubled transatlantic fiber capacity. The industry's capacity across the Atlantic and Pacific, therefore, has undergone explosive growth (Figure 4).

The growth of bandwidth in both satellites and fiber optics carriers has been exponential, and each technology can carry more than 100,000 voice circuits simultaneously. However, because the vast majority of capacity enhancement has occurred in fiber, the fungibility of fiber and satellites has been reduced. Five or 10 years ago, when a submarine cable failed for any reason, the carrier would switch traffic temporarily to a satellite; indeed, serving as backups to cable was a long-standing role of the satellite industry (Maclean 1995). But a satellite transponder can beam only about 64 megabits (mbps) of information per second (newer, more powerful ones capable of 155 mbps are under development). Given this constraint, many users switched to fiber.

Not surprisingly, this surge in supply in the fiber optics industry ultimately led to overcapacity and declining utilization rates (ElBoghdady 2001). By 2003, overall capacity utilization rates were below 50 percent, leading to large

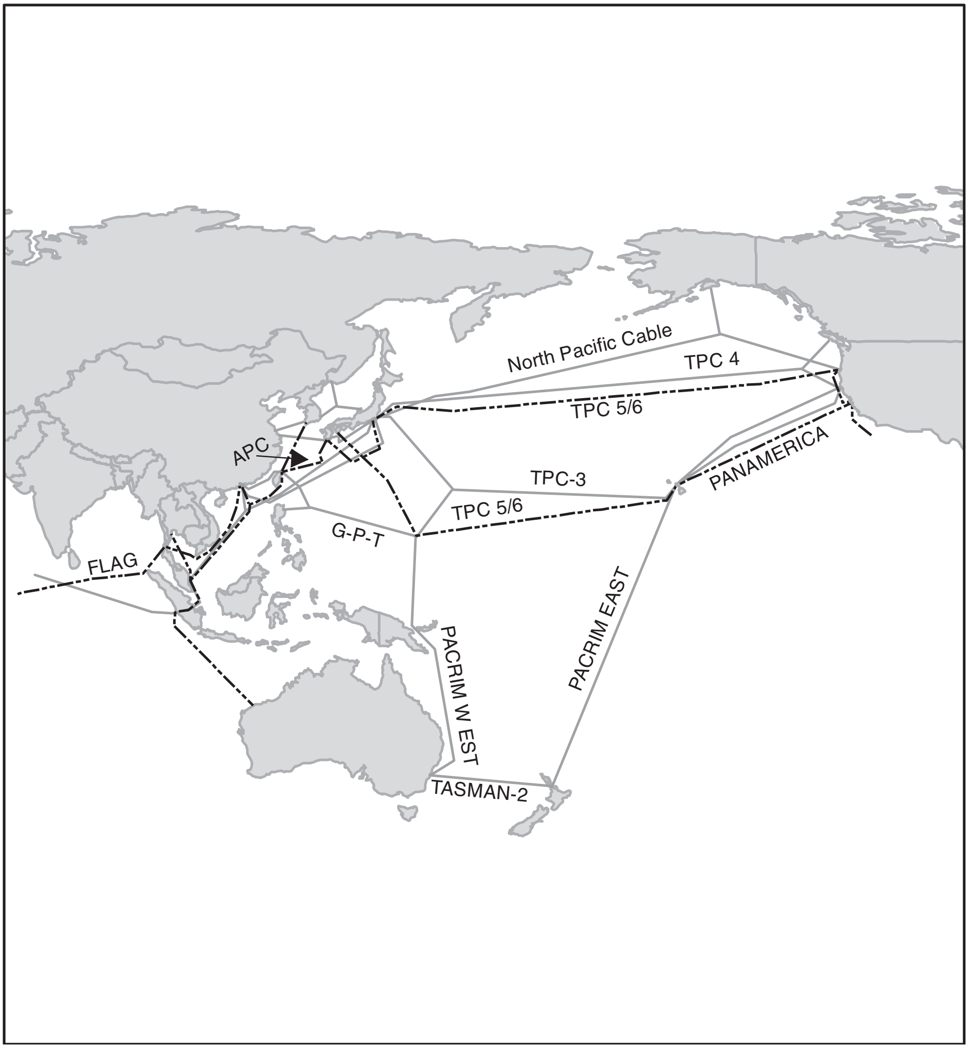

Figure 3 *Transpacific fiber lines.*
Source: Redrawn from Staple (2004).

quantities of unused “dark fiber.” Transmission prices, accordingly, plunged in the late 1990s, often by as much as 90 percent (Figure 5). For example, on the main transatlantic cables, “the cost per bit has plummeted from $650,000 for each Mbit/sec on TAT-8 to just $400 per Mbit/sec on the upcoming FA-1” (Network Magazine 2002). The glut of fiber capacity initiated a deflationary spiral that forced some firms into bankruptcy (e.g., the giant Global Crossing) and almost all others into financial restructuring. Satellite firms, hurt by the stampede to fiber, relished the irony. However, excess capacity and low prices in the fiber industry also made the transmission mode attractive to media firms, which were relatively late to switch from satellites. Some broadcasting networks, such as Fox Communications, already rely on fiber for point-to-point video transmission (Pfeifenberger and Houthakker 1998).

Competition, deregulation, and technological change also spurred a revival of satellite

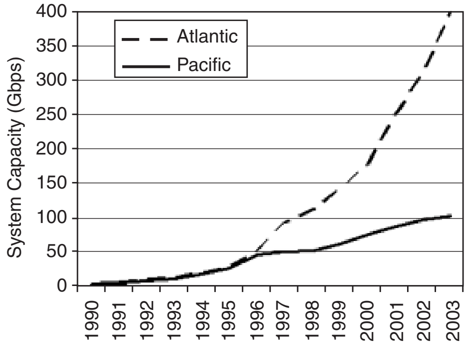

Figure 4 *Changing total capacities in global fiber optic cable network.*
Source: Author, based on data from Staple (2004).

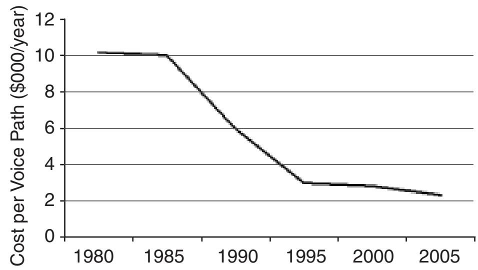

Figure 6 *Declining costs in Intelsat services.*
Source: International Telecommunications Union (www.itu.int/osg/spu/intset).

services, including newer, more powerful satellites with lower rates of interruption (Lane 1996). Although fewer satellites are launched today than in the past, their transmission capabilities are so large as to increase overall industry capacity. The entry of Russian providers in the commercial satellite launch market drove prices down in that arena. The industry responded to the rising challenge posed by fiber with its own technical changes, including onboard processing, digital compression, dynamic routing through the satellite mesh, multibeam antennas, and cheaper earth stations. Accordingly, even the industry's 800-pound gorilla, Intelsat, was forced to drop its prices significantly (Figure 6). Today, Intelsat accounts for roughly 37 percent of global commercial satellite capacity and only 20 percent (or less) of the transatlantic market and 12 percent (or less) of the transpacific market (Pfeifenberger and Houthakker 1998).

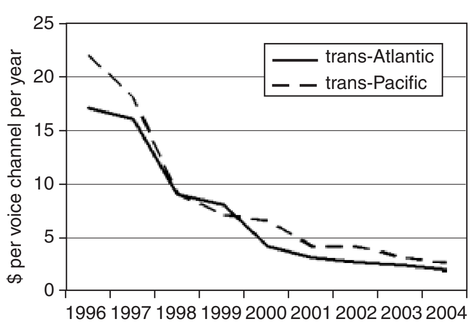

Figure 5 *Cost reductions in fiber services.*
Source: Based on www.fiber-exchange.com.

Simultaneously, the rapid growth of wireless technologies and cellular phone markets fostered the widespread deployment of small, low-orbiting satellites. Large satellites capable of handling international traffic sit 22,300 miles high in geostationary orbit; from such a vantage point, a satellite can "see" and transmit to (i.e., leave a "footprint" over) approximately 40 percent of the earth's surface. The rapid growth of cellular traffic, however, has encouraged the deployment of small direct broadcast satellites (DBSs) positioned only a few hundred miles high, oriented to very small antennas, and possessing relatively small footprints: when microwave signals are sent great lengths and become broadly diffused, as is the case in international telephone and video traffic, earth stations must have large and powerful antennas to receive them. Large numbers of cell phone users (more than half the population in Scandinavia, and upwards of one-third in the United States) have generated a steady growth in the demand for satellite services; today, three-quarters of all satellites launched serve the wireless market (Cole 1997; Vartabedian 1998). As Pelton (1997, 339) has argued, this phenomenon may reverse the declining fortunes of satellite operators: "Satellites will assume a new role. No longer will satellites serve as a 'poor relative' working to support terrestrial fiber optic systems by providing connections just to rural and remote areas or relieve terrestrial network congestion. The satellite communications systems will in fact bypass the terrestrial networks and provide direct services to the home and office."

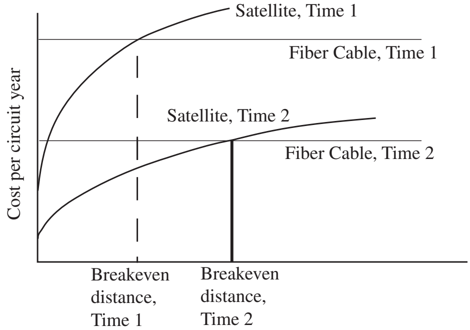

Figure 7 *Satellite and fiber transmissions costs over distance at two moments in time.*
Source: Based on Langdale (1989).

The competitive ability between satellites and fiber lines varies over time and with transmission distance. Satellites have traditionally been more cost-effective for longer distances (more than 500 miles), and fiber optic lines often provide cheaper service for shorter routes (Langdale 1989). Satellites face higher fixed costs than do fiber optic carriers (particularly launch costs), but their marginal costs are zero over distance; within the footprint of a satellite it achieves total time-space convergence. Fiber optic carriers face relatively low fixed costs, but logarithmically increasing marginal costs over distance (largely in the form of repeaters, but also maintenance costs). In the past decade, both technologies have become significantly able to provide better, cheaper, and more reliable service over longer distances. Technological improvements, however, have progressively extended the break-even distance over time, primarily to the loss of satellite providers and the gain of their competitors (Figure 7).

International Capacity and Traffic

The complex interplay of deregulation, globalization, and technological change has increased explosively the international transmission capacities and traffic volumes for both satellite and fiber optics carriers (Table 3). From 1988 to 2003, for example, transatlantic fiber optic cable capacity increased from 43,750 voice paths to 45.1 billion (103,000 percent), and satellite capacity along the same route rose from 78,000 voice paths to 2.26 billion (2,803 percent).

Table 3 *Fiber and satellite voice paths, 1988–2003 (thousands)*

	Transatlantic		Transpacific	
	Fiber	Satellite	Fiber	Satellite
1988	43.8	78.0	1.9	39.0
1989	43.8	93.0	43.8	39.0
1990	175.0	283.0	43.8	39.0
1991	175.0	283.0	135.0	47.0
1992	437.5	496.0	222.5	47.0
1993	568.8	620.8	222.5	83.3
1994	1,090.6	620.8	310.0	234.0
1995	1,481.3	710.8	310.0	283.1
1996	1,481.3	710.8	310.0	351.1
1997	3,825.0	835.8	614.0	431.8
1998	5,135.6	922.0	1,219.0	557.1
1999	7,340.6	1,048.3	1,872.5	757.6
2000	13,947.2	1,299.9	3,932.3	924.3
2001	29,289.1	1,416.9	8,651.0	1,173.9
2002	41,004.7	1,728.6	15,571.7	1,396.9
2003	45,105.2	2,264.5	19,776.1	1,648.3

Source: Computed from data in Staple (2004).

Across the Pacific Ocean, cable carriers' capacity rose from 1,800 voice paths to 1.87 billion (an astonishing 1.6 billion percent), while satellite capacity over the same route rose from 39,000 voice paths to 1.6 billion (4,127 percent). In 2003, fiber optics carriers comprised 94.4 percent of worldwide transmission capacity (up from 16 percent in 1988), including 91.3 percent across the Pacific and 95.2 percent across the Atlantic Ocean (Table 4). The marginally better capacity of satellites to serve the Pacific rather than the Atlantic market may reflect the longer distances involved, the subsequently higher marginal costs of cable carriers (which are better justified in the transatlantic market, traffic over which is substantially larger), and the low-density markets of the south Pacific islands.

Table 4 *Market shares of satellite and fiber optic carriers in two markets, 1988 and 2003 (percentage of total voice paths)*

Carrier\Market	Atlantic	Pacific	Total
1988			
Fiber	35.9	4.5	16.2
Satellite	64.1	95.5	83.8
Total	100.0	100.0	100.0
2003			
Fiber	96.7	95.9	96.4
Satellite	3.3	4.1	3.6
Total	100.0	100.0	100.0

Source: Computed from data in Staple (2004).

During the 1990s fiber optic cable carriers shifted from their position as tiny competitors of satellite providers to surpassing satellites by dramatic margins in total capacity, a reflection of the extension of changing break-bulk distances discussed above. In short, fiber optics carriers today overwhelmingly dominate the market for international telecommunications to the point that satellites have been largely excluded from private commercial uses.

Concluding Comments

The disintegration of the stable world of telecommunications (i.e., POTS), a product of worldwide deregulation and globalization, ushered in numerous important economic and technological changes. The new environment has encouraged and facilitated numerous new telecommunications providers to enter the market, intensified competition, and ended Intelsat's satellite monopoly. The explosive growth of fiber cable systems across the globe has led to enormous increases in transmission capacity, a glut in supply, and severe price deflation. Geographically, the transatlantic and transpacific markets remain the most important for international telecommunications, although the last ten years have also witnessed rapid growth in Latin America and Asia.

Although their transmission costs have also declined, satellites have failed to match the latest leaps in fiber optics capacity and can compete with transoceanic submarine cables only with great and mounting difficulty; today, 94 percent of all international telecommunications is transmitted via cables. As their competitive edge has eroded, satellite providers have been steadily forced to serve markets in low-density regions, which are relatively low-profit arenas compared to the lucrative high-volume, corporate data transmissions market. However, the full impacts of the cellular revolution in telecommunications, including wireless phones, GPS systems and satellite radio, which favor low-orbiting satellites, have yet to be felt. Some observers maintain that the long-standing rivalry between satellite and fiber optics may draw to a close as some firms experiment with hybrid service delivery (Singhi and Long 1998). In short, the heated competition between these two quasi-fungible technologies, which often serve distinct market segments, has yet to end, and will play an important role in the emerging geographies of information transmission in the future, much as they have done in the recent past. ■

Literature Cited

Akwule, R. 1992. *Global telecommunications: The technology, administration, and policies*. Boston: Focal Press.

Cairncross, F. 1997. *The death of distance*. Boston: Harvard Business School Press.

Castells, M. 1996. *The rise of the network society*. Oxford, U.K.: Blackwell.

Cole, J. 1997. New satellite era looms just over the horizon. *Wall Street Journal* 18 March: B1–2.

Crampton, J. 2003. *The political mapping of cyberspace*. Edinburgh, U.K.: Edinburgh University Press.

Denniston, F. 1998. FLAG–Fiber-optic Link Around the Globe. *Sea Technology* February: 78–83.

Dicken, P. 2004. *Global shift: The internationalization of economic activity*, 4th ed. New York: Guilford Press.

Drake, W., and E. Noam. 1998. Assessing the WTO agreement on basic telecommunications. In *Unfinished business: Telecommunications after the Uruguay Round*, ed. G. Hufbauer and E. Wada, 27–61. Washington, DC: Institute for International Economics.

ElBoghdady, D. 2001. Fiber-optic firms face issue of overbuilding. *Washington Post* 28 February: 1.

Fiber exchange. www.fiber-exchange.com (last accessed August 2004).

Graham, S. 1999. Global grids of glass: On global cities, telecommunications, and planetary urban networks. *Urban Studies* 36:929–49.

Graham, S., and S. Marvin. 1996. *Telecommunications and the city: Electronic spaces, urban places*. London: Routledge.

Harwood, J., W. Lake, and D. Sohn. 1997. Competition in international telecommunications services. *Columbia Law Review* 97:874–904.

Hillis, K. 1998. On the margins: The invisibility of communications in geography. *Progress in Human Geography* 22:543–566.

Hugill, P. 1999. *Global communications since 1844: Geopolitics and technology*. Baltimore: Johns Hopkins University Press.

International Telecommunications Union. www.itu.int/osg/spu/intset. (last accessed August 2004).

Kellerman, A. 2002. *The Internet on Earth: A geography of information*. New York: Wiley.

Kildow, J. 1973. *INTELSAT: Policy-maker's dilemma*. Lexington, MA: Lexington Books.

Kinsley, M. 1976. *Outer space and inner sanctums: Government, business, and satellite communication*. New York: Wiley.

Landler, M. 1995. Satellite services hear the naysayers. *New York Times* 4 October: C4.

Lane, C. 1996. The satellite revolution. *The New Republic* 12 August: 22–24.

Langdale, J. 1989. The geography of international business telecommunications: The role of leased networks. *Annals of the Association of American Geographers* 79:501–22.

Layton, R. 1986. Will satellites and optical fiber collide or coexist? In *Tracing new orbits*, ed. D. Demac, 79–90. New York: Columbia University Press.

Leyshon, A. 1992. The transformation of regulatory order: Regulating the global economy and environment. *Geoforum* 23:249–67.

Maclean, G. 1995. Will fiber optics threaten satellite communications? *Space Policy* 11:95–99.

Malecki, E. 2001. The economic geography of the Internet's infrastructure. *Economic Geography* 77:399–424.

Massey, D. 1984. *Spatial divisions of labor*. New York: Methuen.

———. 1993. Power-geometry and a progressive sense of place. In *Mapping the futures: Local cultures, global change*, ed. J. Bird, B. Curtis, T. Putnam, G. Robertson, and L. Tickner, 59–69. London: Routledge.

Monmonier, M. 2002. *Spying with maps*. Chicago: University of Chicago Press.

Network Magazine. 2002. www.networkmagazine.com (last accessed August 2004).

Nijkamp, P., and J. Vleugel. 1993. Submarine cables in our times: Competition between seacables and satellites. In *Corporate networks, international telecommunications and interdependence: Perspectives from geography and information systems*, ed. H. Bakis, R. Abler, and E. Roche, 89–97. London: Belhaven Press.

Pelton, J. 1997. Learning via satellite. *Space Policy* 13:339–43.

Pfeifenberger, J., and H. Houthakker. 1998. Competition to international satellite communications services. *Information Economics and Policy* 10:403–30.

Price, C. 1998. Privatisation plan by satellite operators. *Financial Times* 1 April: 5.

Sassen, S. 2000. *Cities in a world economy*, 2nd ed. Thousand Oaks, CA: Pine Forge Press.

Schiller, D. 1999. *Digital capitalism: Networking the global market system*. Cambridge, MA: MIT Press.

Silverstein, S. 2001. Top 20 fixed satellite operators. *SpaceNews*. www.space.com/spacenews/top20_satellite_2001 (last accessed August 2004).

Singhi, M., and H. Long. 1998. New undersea cable developments and satellite services: Toward complementary coexistence in the 21st century. In *Proceedings of the 20th Pacific Telecommunications Conference*, 566–69. Honolulu: Pacific Telecommunications Council.

Staple, G. 2004. *Telegeography 2004: Global telecommunications traffic statistics and commentary*. Washington, DC: Telegeography, Inc.

Tickell, A., and J. Peck. 1995. Social regulation after Fordism: Regulation theory, neo-liberalism, and the global-local nexus. *Economy and Society* 24:357–86.

Vartabedian, R. 1998. Commercial satellite boom boosts firms to new heights. *Los Angeles Times* June 16 A1: 22–23.

Walcott, S., and J. Wheeler. 2001. Atlanta in the telecommunications age: The fiber-optic information network. *Urban Geography* 22:316–39.

Warf, B. 1995. Telecommunications and the changing geographies of knowledge transmission in the late 20th century. *Urban Studies* 32:361–78.

———. 1998. Reach out and touch someone: AT&T's global operations in the 1990s. *The Professional Geographer* 50:255–67.

———. 2003. Mergers and acquisitions in the telecommunications industry. *Growth and Change* 34:321–44.

Wheeler, J., Y. Aoyama, and B. Warf, eds. 2000. *Cities in the telecommunications age: The fracturing of geographies*. London: Routledge.

Wilson, M., and K. Corey, eds. 2000. *Information tectonics: Space, place, and technology in an electronic age*. New York: Chichester.

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